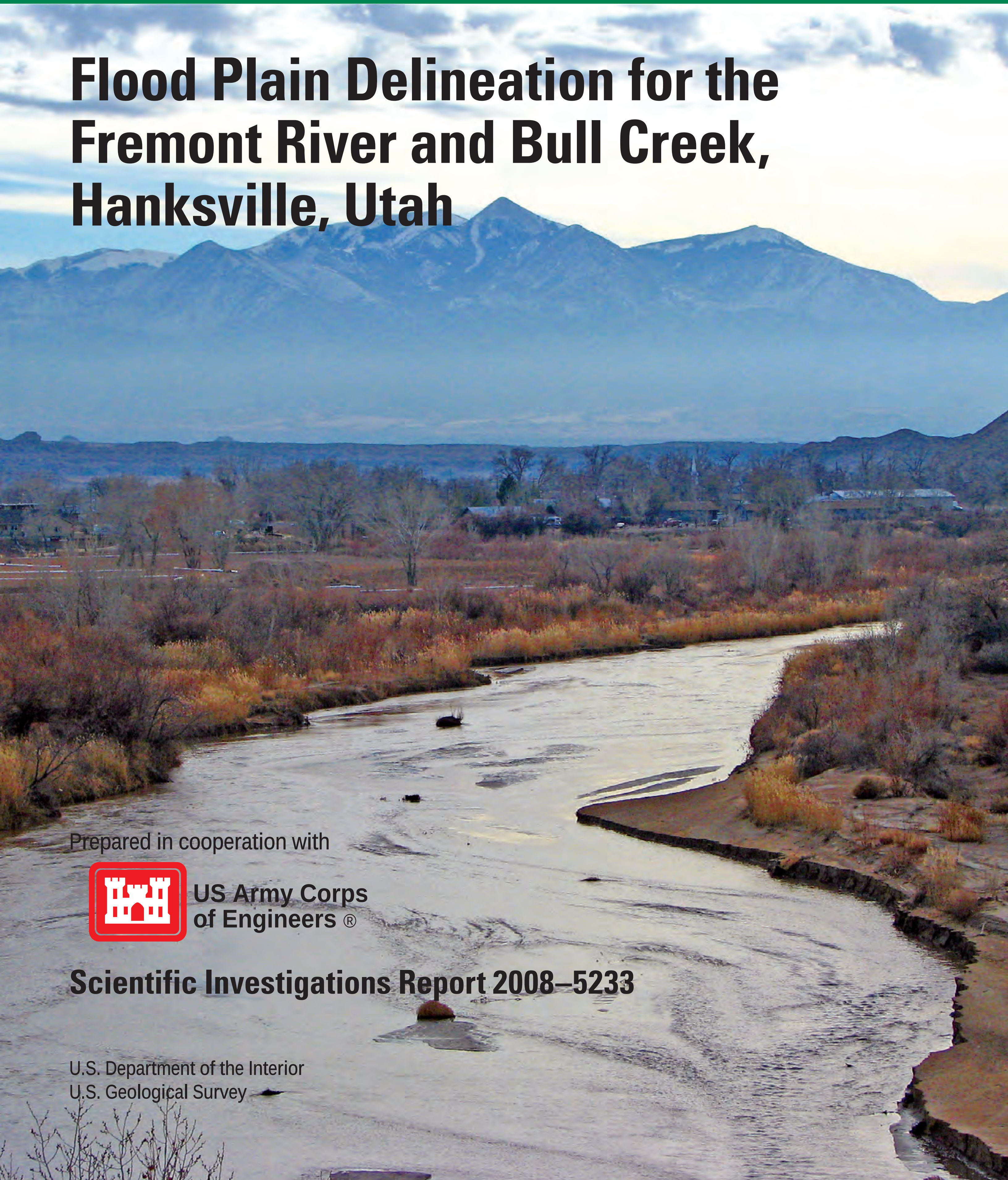

Flood Plain Delineation for the Fremont River and Bull Creek, Hanksville, Utah

Prepared in cooperation with

US Army Corps of Engineers ®

Scientific Investigations Report 2008–5233

U.S. Department of the Interior
U.S. Geological Survey

Cover photo: Looking upstream, view of Fremont River north of Hanksville, Utah. Source: Terry Kenney, USGS, 2007.

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U.S. Geological Survey
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Conversion Factors and Datums

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Acronyms Used in the Text

(Clarification or additional information given in parentheses)

DEM	Digital Elevation Model
ESRI	Environmental Systems Research Institute
FPMS	Flood Plain Management Services (USACE)
GIS	geographic information system
HEC-RAS	Hydrologic Engineering Center River Analysis System
MD_SWMS	Multi-Dimensional Surface Water Modeling System (USGS)
NED	National Elevation Dataset (USGS)
NGS	National Geodetic Survey
NSRS	National Spatial Reference System
OPUS	Online Positioning User Service
RTK-GPS	real-time kinematic global positioning system
SAM	Slope Area Measurement
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Flood Plain Delineation for the Fremont River and Bull Creek, Hanksville, Utah

By Terry A. Kenney and Susan G. Buto

Abstract

Predicted inundation maps for the Fremont River and Bull Creek in Hanksville, Utah, were developed using one-dimensional hydraulic models. Estimates of the 1-percent chance (100-year) peak streamflows were determined for the Fremont River and Bull Creek study reaches by using annual peak series data from streamflow-gaging stations and regional peak-flow regression equations. Surveyed topographic data for the study reaches were processed for use in the one-dimensional hydraulic models. The 1-percent chance (100-year) peak streamflows were simulated with hydraulic models to obtain predicted water-surface elevations. Water-surface elevations were then used to map the predicted inundation on a recent aerial photograph. The 1-percent chance (100-year) flood plain for the Fremont River in Hanksville, Utah, included some agricultural lands and did not encroach upon the town. The 1-percent chance (100-year) flood plain on the west side of Bull Creek was found to include a large portion of the town of Hanksville, Utah.

Introduction

The Fremont River and Bull Creek flow adjacent to and through Hanksville, Utah, respectively (fig. 1). To date, the flood plains associated with the 1-percent chance (100-year) peak streamflows have not been defined for these streams. A delineated flood plain provides a tool for municipal and county managers to help mitigate future flood-related loss of life and property. Section 206 of the Flood Control Act of 1960 (PL86-645, as amended) provides the U.S. Army Corps of Engineers (USACE), through its Flood Plain Management Services (FPMS) program, with resources to aid communities, such as Hanksville, with flood plain issues. The U.S. Geological Survey (USGS), in cooperation with the USACE, completed this study to delineate the 1 percent chance flood plains for the Fremont River and Bull Creek in Hanksville, Utah. This flood plain investigation is considered to be a nondetailed study under the USACE's FPMS program and the results are not for use in flood insurance rate determinations.

Purpose and Scope

This report documents the development of inundation maps associated with the 1-percent chance (100-year) peak streamflows for the Fremont River and Bull Creek in Hanksville, Utah. Methods used in determining the 1-percent chance (100-year) peak streamflows for these study reaches are described. The approaches taken in the development of the one-dimensional hydraulic models used to simulate the 1-percent chance (100-year) peak streamflows for the Fremont River and Bull Creek study reaches are outlined. Finally, limitations associated with the interpretation of the results generated from this study are discussed.

Description of Study Area

Hanksville, Utah, a rural community with a population of approximately 200, is located in southeastern Utah. The Fremont River at Utah State Road 24 has a drainage area of 1,930 mi^2 and drains the Fish Lake Hightop and Awapa Plateaus. Peak flows of the Fremont River are dominated by late summer monsoonal rainfall events (table 1), which characteristically are of short duration and high magnitude. Near Hanksville, Utah, the Fremont River generally meanders in a northeasterly direction within a well-defined flood plain that is bound in most locations by steep banks that on average exceed 10 ft in height (fig. 2). Channel materials in this reach of the Fremont River are primarily sand and silt with some gravels. Vegetation in the flood plain ranges from sparse desert plants, such as sagebrush and rabbit brush, to dense stands of cottonwoods, willows, and tamarisk or salt cedar. The average channel slope of the Fremont River is 0.0021 ft/ft in the study reach.

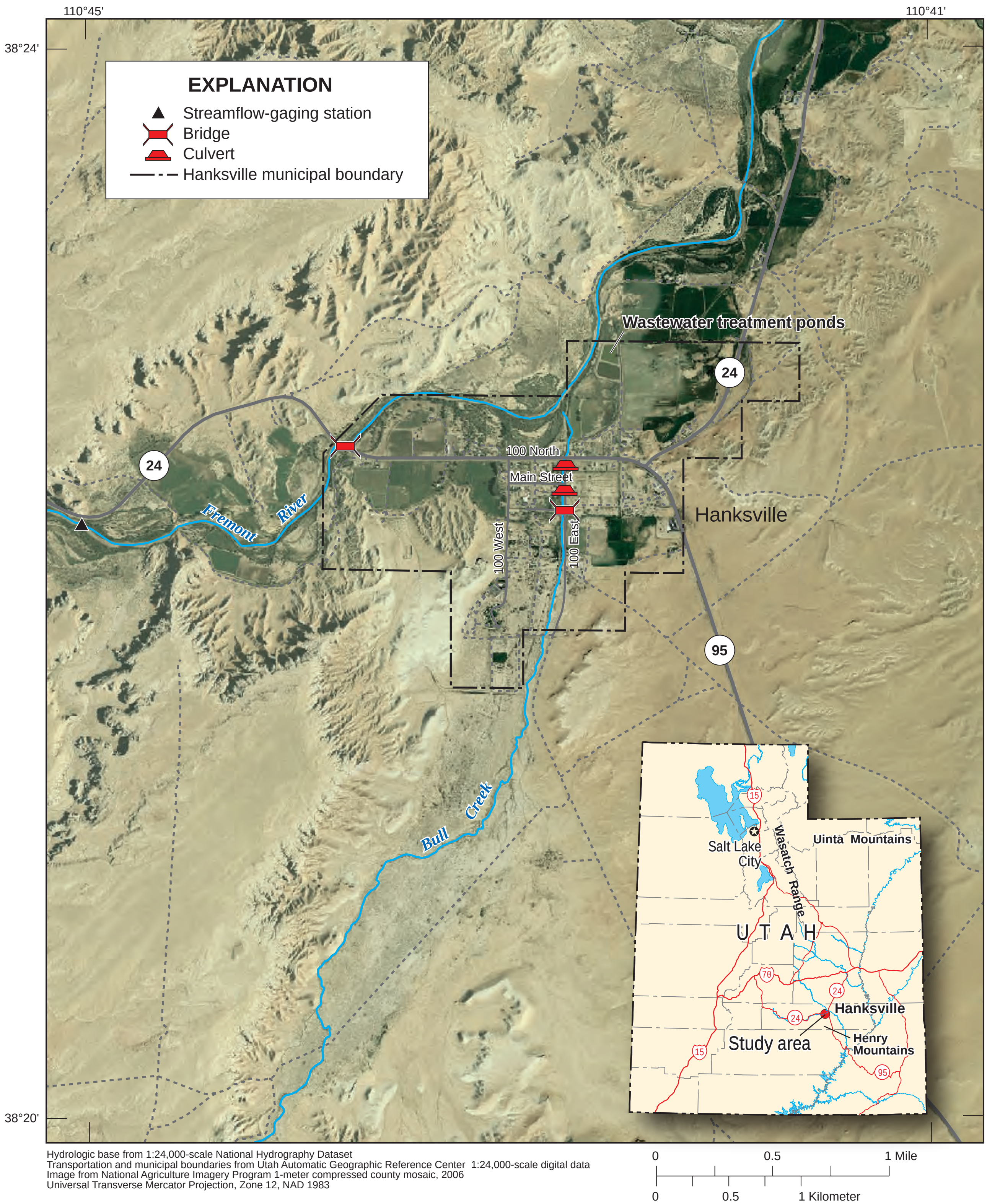

Figure 1. Location of Fremont River and Bull Creek study reaches near Hanksville, Utah.

Table 1. Annual (water year, October–September) peak streamflows for USGS streamflow-gaging stations 09330400, Fremont River near Hanksville, Utah, and 09333500 Dirty Devil River above Poison Spring near Hanksville, Utah.

[—, no data]

Gaging station 09330400 Fremont River near Hanksville, Utah		Gaging station 09333500 Dirty Devil River above Poison Spring Wash near Hanksville, Utah	
Date	Peak streamflow, in cubic feet per second	Date	Peak streamflow, in cubic feet per second
—	—	August 5, 1948	8,680
—	—	July 5, 1949	3,120
—	—	July 9, 1950	11,300
—	—	August 4, 1951	12,800
—	—	September 22, 1952	8,870
—	—	August 22, 1953	6,390
—	—	September 14, 1954	2,690
—	—	October 8, 1954	3,420
—	—	July 1, 1956	6,360
—	—	August 31, 1957	11,360
—	—	November 4, 1957	35,000
August 12, 1959	5,620	August 13, 1959	3,830
September 6, 1960	1,400	November 3, 1959	975
September 9, 1961	6,500	September 9, 1961	21,000
September 28, 1962	4,300	September 21, 1962	2,810
September 3, 1963	6,140	September 1, 1963	12,200
July 31, 1964	2,660	October 21, 1963	1,720
August 18, 1965	6,850	August 17, 1965	10,700
August 31, 1966	3,360	August 19, 1966	3,000
August 9, 1967	1,330	September 9, 1967	3,100
August 1, 1968	3,080	July 31, 1968	5,540
August 29, 1969	8,500	June 24, 1969	3,300
September 6, 1970	4,300	August 4, 1970	6,500
August 26, 1971	4,200	August 31, 1971	2,180
August 27, 1972	3,600	August 20, 1972	3,530
October 19, 1972	15,300	October 19, 1972	10,200
—	—	March 3, 1974	281
—	—	November 3, 1974	742
—	—	May 7, 1976	4,000
—	—	July 25, 1977	5,690
—	—	July 4, 1978	1,710
—	—	November 3, 1978	11,500
—	—	September 10, 1980	25,700
—	—	September 6, 1981	18,300
—	—	June 4, 1905	2,860
—	—	July 3, 1983	948
—	—	July 24, 1984	5,630
—	—	July 19, 1985	2,240
—	—	August 22, 1986	2,370
—	—	July 30, 1987	2,190
—	—	April 18, 1988	620

Table 1. Annual (water year, October–September) peak streamflows for USGS streamflow-gaging stations 09330400, Fremont River near Hanksville, Utah, and 09333500 Dirty Devil River above Poison Spring near Hanksville, Utah—Continued.

[—, no data]

Gaging station 09330400 Fremont River near Hanksville, Utah		Gaging station 09333500 Dirty Devil River above Poison Spring Wash near Hanksville, Utah	
Date	Peak streamflow, in cubic feet per second	Date	Peak streamflow, in cubic feet per second
—	—	August 18, 1989	1,410
—	—	July 8, 1990	2,080
—	—	August 7, 1991	3,000
—	—	July 25, 1992	2,720
—	—	May 17, 1993	700
—	—	September 12, 2002	6,320
—	—	August 24, 2003	1,170
—	—	October 3, 2003	2,030
—	—	September 10, 2005	5,130
—	—	October 19, 2005	12,500
—	—	October 6, 2006	35,800

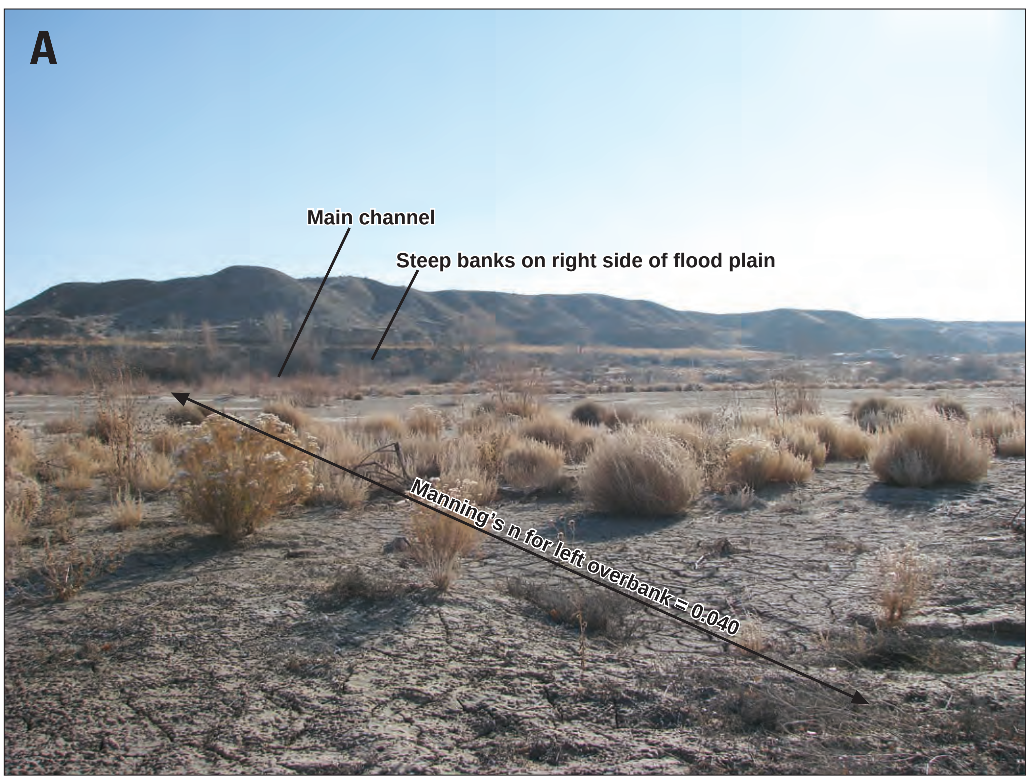

Figure 2. Observed banks on the edge of the Fremont River flood plain, Utah. A. View looking southeast from left flood plain upstream of Utah State Road 24 bridge near cross-sections 38 and 39. Steep banks bounding the right flood plain can be seen. B. View of right flood plain boundary looking east from the right flood plain near cross-sections 29 and 30. C. View looking southwest of left flood plain upstream of Utah State Road 24 Bridge near cross-section 40. D. View looking west across the Fremont River of left flood plain at downstream end of Fremont River study reach near cross-section 4.

Figure 2. Observed banks on the edge of the Fremont River flood plain, Utah. A. View looking southeast from left flood plain upstream of Utah State Road 24 bridge near cross-sections 38 and 39. Steep banks bounding the right flood plain can be seen. B. View of right flood plain boundary looking east from the right flood plain near cross-sections 29 and 30. C. View looking southwest of left flood plain upstream of Utah State Road 24 Bridge near cross-section 40. D. View looking west across the Fremont River of left flood plain at downstream end of Fremont River study reach near cross-section 4—Continued.

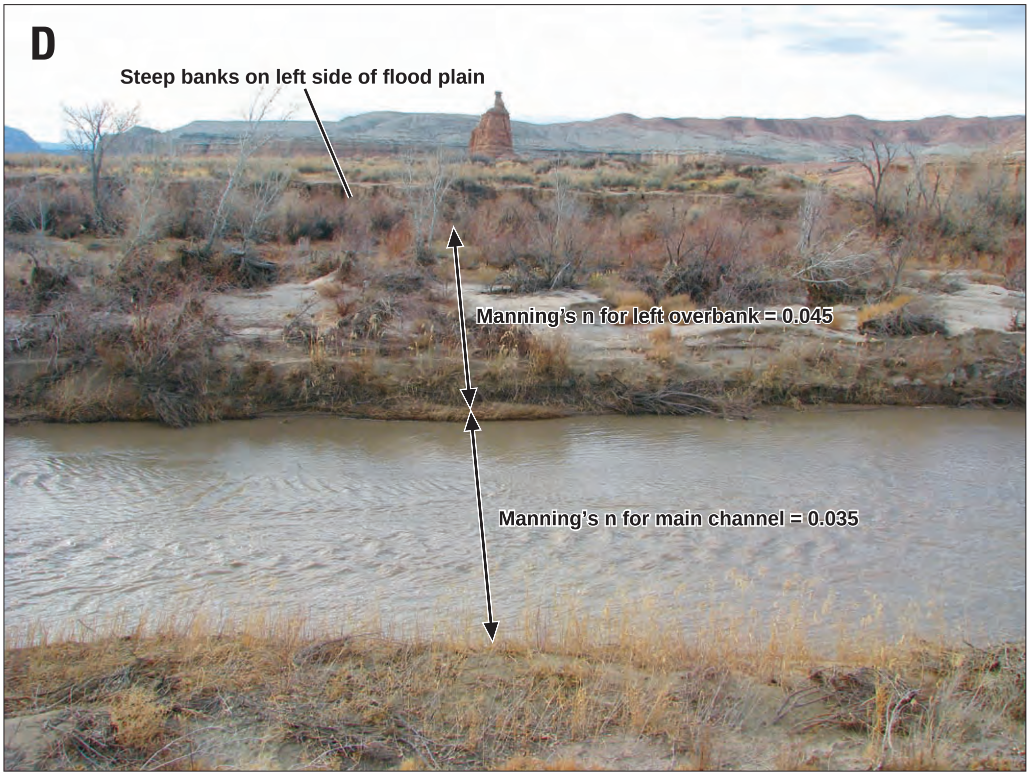

Figure 2. Observed banks on the edge of the Fremont River flood plain, Utah. A. View looking southeast from left flood plain upstream of Utah State Road 24 bridge near cross-sections 38 and 39. Steep banks bounding the right flood plain can be seen. B. View of right flood plain boundary looking east from the right flood plain near cross-sections 29 and 30. C. View looking southwest of left flood plain upstream of Utah State Road 24 Bridge near cross-section 40. D. View looking west across the Fremont River of left flood plain at downstream end of Fremont River study reach near cross-section 4—Continued.

Bull Creek, which originates in the foothills of the Henry Mountains, flows north through Hanksville to its confluence with the Fremont River north of Utah State Road 24 (100 North). The drainage area of Bull Creek at the confluence with the Fremont River is approximately 19 mi^2. Bull Creek in Hanksville is usually dry with most flows being associated with monsoonal rainfall events that occur in the upper part of the drainage. Upstream of town, Bull Creek is entrenched into multiple channels that are vegetated by a variety of desert plants (fig. 3). At the south end of town, Bull Creek is a single engineered earthen trapezoidal channel (fig. 4). Bull Creek terminates as a levee-bound channel that protrudes into the Fremont River flood plain. The average channel slope of the Bull Creek study reach is 0.0087 ft/ft—about four times steeper than the Fremont River study reach.

Flood Plain Delineation

Hydrologic and hydraulic analyses were required to delineate the 1-percent chance (100-year) flood plains for the Fremont River and Bull Creek study reaches in Hanksville, Utah. Streamflow gaging-station records and regional flood-frequency regression equations were used to estimate the 1-percent chance peak streamflows for each study reach. Hydraulic models were developed to determine the associated inundation area or flood plain for each reach by using the USACE Hydrologic Engineering Center River Analysis System (HEC-RAS).

Hydrologic Analyses

For this flood plain study, estimates of the 1-percent chance peak streamflows were determined for the Fremont River and Bull Creek at Hanksville, Utah. The 1-percent chance peak streamflow, often termed the "100-year streamflow," is the maximum instantaneous streamflow that has a 1-percent chance of occurring in any given year. Estimates of these streamflows were obtained following the methods of Bulletin 17B (U.S. Interagency Advisory Committee on Water Data, 1982). Streamflow gaging-station records and regional flood-frequency regression equations (Kenney and others, 2007) were used to estimate the 1 percent chance peak streamflows.

Fremont River

The 1-percent peak streamflow for the Fremont River study reach in Hanksville, Utah, was determined by using the techniques in Bulletin 17B (U.S. Interagency Advisory Com-

Figure 3. Upstream view of Bull Creek south of Hanksville, Utah, near cross-section 11.

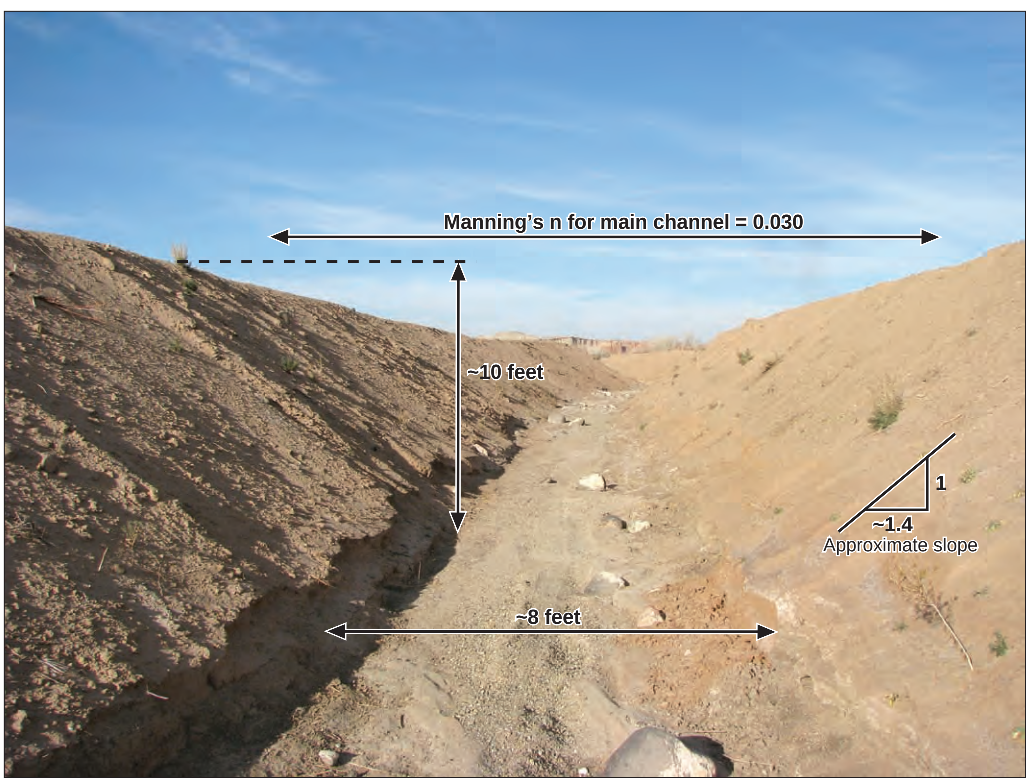

Figure 4. Downstream view of Bull Creek south of Hanksville, Utah, near cross-section 8.

mittee on Water Data, 1982) for locations with systematic gaging-station data. Fifteen annual peak streamflows were available for USGS crest-stage gaging station 09330400, Fremont River near Hanksville, Utah, located immediately upstream of the study reach (fig. 1). A crest-stage gaging station records maximum river stage, or water-surface elevation, which is then applied to the site-specific river stage-streamflow rating table to determine the associated streamflow. Traditional, or continuous, streamflow-gaging stations record river stage continuously at intervals ranging from about 15 minutes to 1 hour, whereas crest-stage gaging stations record only the maximum river stage between visits. The period of record for the Fremont River near Hanksville, Utah, station includes water years 1959 through 1973 (table 1). These annual peaks were fit to a log-Pearson Type III (LPIII) probability distribution by using the equation (U.S. Interagency Advisory Committee on Water Data, 1982):

$$\log Q_T = \bar{X} + KS \qquad (1)$$

where:

- Q_T is the T-year peak flow, in cubic feet per second, where T is recurrence interval,
- $\bar{X}$ is the mean of the log-transformed annual peak flow,
- K is the frequency factor dependent on the recurrence interval and the weighted skew coefficient of the log-transformed annual peak flow, and
- S is the standard deviation of the log-transformed annual peak flows.

A generalized skew of 0, which is contained in term K, was determined from the generalized skew map of Perica and Stayner (2004). From this LPIII fitting, the 1-percent chance peak streamflow was determined to be 18,400 ft^3/s. The upper and lower 95-percent confidence intervals for this estimate are 38,400 ft^3/s and 12,100 ft^3/s, respectively. An effort was made to adjust the relatively short annual peak flow record of 15 years for the Fremont River near Hanksville, Utah, station using the two-station comparison technique (U.S. Interagency Advisory Committee on Water Data, 1982). Comparison was made with downstream USGS streamflow-gaging station 09333500, Dirty Devil River above Poison Spring Wash, near Hanksville, Utah, which has a period of record of 52 years, and which includes the 15 years of record of the Fremont River near Hanksville, Utah, station (table 1). The two-station comparison resulted in the 1-percent chance peak streamflow for the Fremont River near Hanksville, Utah, station to be adjusted to 21,400 ft^3/s. This adjusted 1-percent chance streamflow has 21 years of equivalent record, 6 more than the Fremont River near Hanksville, Utah, station.

Bull Creek

No systematic gaging-station data are available for the Bull Creek study reach. However, a USGS streamflow-gaging station was previously located on Bull Creek roughly 6 mi upstream of Hanksville, Utah, and provided nine annual peak streamflows, from 1983 to 1991. Using these data, an LPIII analysis as described above determined the 1-percent chance peak streamflow for USGS streamflow-gaging station 09330410, Bull Creek near Hanksville, Utah, to be 1,400 ft^3/s. The upper and lower 95-percent confidence intervals for this estimate are 29,700 and 332 ft^3/s, respectively. In an effort to improve this estimate, USGS streamflow-gaging stations within 50 mi were examined for use as a comparison station. Of seven stations examined, streamflow-gaging station 09329050 Seven Mile Creek near Fish Lake, Utah, which has a period of record of 34 years that includes the 9 years of record of the Bull Creek near Hanksville, Utah, station, compared most favorably based upon the guidelines in Bulletin 17B (U.S. Interagency Advisory Committee on Water Data, 1982) for a two-station comparison (table 2). Following the techniques in Bulletin 17B, the 1-percent chance peak streamflow for the Bull Creek near Hanksville, Utah, station was adjusted to 1,550 ft^3/s. This adjusted 1-percent chance peak streamflow has 12 years of equivalent record, 3 more than that associated with the Bull Creek near Hanksville, Utah, station. An estimate of the 1-percent chance peak streamflow for the Bull Creek study reach in Hanksville, Utah, was determined to be 2,080 ft^3/s by weighting the adjusted LPIII determined 1-percent chance peak streamflow by area using the equation (Guimaraes and Bohman, 1992; Stamey and Hess, 1993):

$$Q_{T(u)} = Q_{T(g)} \left(DA_u / DA_g \right)^a \qquad (2)$$

where:

- $Q_{T(u)}$ is the T-year peak flow for the ungaged site, in cubic feet per second, where T is recurrence interval,
- $Q_{T(g)}$ is the T-year peak flow for the gaged site, in cubic feet per second, where T is recurrence interval
- DA_u is the drainage area for the ungaged site,
- DA_g is the drainage area for the gaged site, and
- a is an exponent for the drainage area specific to hydrologic region (0.31 for Utah Region 6 [Kenney and others, 2007]).

The ratio of drainage areas of the study reach (ungaged) and the gaging station is 2.5. This exceeds 1.5 which is the recommended value associated with equation 2. Also, the adjusted gaging station-data represent 12 years of record, a less than preferred amount.

A second method for determining the 1-percent chance peak streamflow for Bull Creek employed the most recent version of flood-frequency regional-regression equations for Utah (Kenney and others, 2007). Using the 100-year recurrence interval regression equation for Utah region 6, the 1-percent chance peak streamflow for the Bull Creek study reach was determined to be 7,190 ft^3/s. Uncertainty, presented as the average standard error of prediction for the equation used is 61 percent.

Table 2. Annual (water year, October–September) peak streamflows for USGS streamflow-gaging stations 09330410, Bull Creek near Hanksville, Utah, and 09329050, Seven Mile Creek near Fish Lake, Utah.

[—, no data; e, estimate]

Gaging station 09330410 Bull Creek near Hanksville, Utah		Gaging station 09329050 Seven Mile Creek near Fish Lake, Utah	
Date	Peak streamflow, in cubic feet per second	Date	Peak streamflow, in cubic feet per second
—	—	June 5, 1965	206
—	—	May 1, 1966	64
—	—	May 22, 1967	126
—	—	June 1, 1968	215
—	—	June 24, 1969	187
—	—	May 28, 1970	209
—	—	May 27, 1971	115
—	—	May 5, 1972	64
—	—	May 18, 1973	190
—	—	May 16, 1974	206
—	—	June 5, 1975	187
—	—	May 18, 1976	160
—	—	April 17, 1977	59
—	—	May 30, 1978	128
—	—	May 29, 1979	225
—	—	June 5, 1980	214
—	—	April 30, 1981	170
—	—	May 25, 1982	212
August 5, 1983	e 200	June 10, 1983	314
July 25, 1984	e 200	June 1, 1984	369
July 19, 1985	e 60	May 4, 1985	86
May 26, 1986	27	May 26, 1986	290
May 15, 1987	19	May 7, 1987	201
August 26, 1988	106	May 14, 1988	235
August 17, 1989	9.8	April 21, 1989	86
September 2, 1990	3.2	May 7, 1990	40
May 31, 1991	1.3	June 3, 1991	145

The uncertainties in the results from the two methods used to determine the 1-percent chance peak streamflow, specifically those associated with transferring gaging-station data from an upstream location of considerably less drainage area, and the large standard error of prediction of the regression equation for the Bull Creek study reach are not ideal. In an effort to take advantage of the benefits of both the empirical data from the gaging station and regional peak streamflow relations contained in the regression equation, the two estimates of the 1-percent chance peak streamflow for the Bull Creek study reach were used to obtain a weighted estimate of 3,960 ft^3/s on the basis of their equivalent years of record by using the equation (Ries and Crouse, 2002):

$$\log Q_{T(G)w} = \frac{(N \log Q_{T(G)s} + EQ \log Q_{T(G)r})}{N + EQ} \quad (3)$$

where:

$Q_{T(G)w}$ is the weighted T-year peak flow estimate, in cubic feet per second, where T is recurrence interval,

$Q_{T(G)s}$ is the T-year peak flow estimate, in cubic feet per second, derived from the systematic flood peaks,

$Q_{T(G)r}$ is the T-year peak flow estimate, in cubic feet per second, derived from the regression equation,

N is the number of years of peak record, and

EQ is the equivalent years of record associated with the regression equation.

Hydraulic Analyses

Hydraulic models were developed for each study reach using the USACE Hydrologic Engineering Center River Analysis System (HEC-RAS). This model simulates open-channel flow in one dimension and requires data specific for the conveyance of water including channel geometry, and friction or roughness properties. One-dimensional hydraulic models typically require geometric reach data in the form of cross-sections that are surveyed to the same vertical datum. HEC-RAS, like most one-dimensional modeling systems, does not readily import unique data points in survey coordinate format, but rather imports delineated cross-sections. Cross-sections in HEC-RAS are defined by their location downstream, or river station, and elevations defining the cross-section shape are referenced by their cross-stream distance, or cross-section stationing. For these reasons, acquired survey data points in X, Y, and Z coordinate format required processing with other software packages prior to import into HEC-RAS. For the Fremont River study reach, which contains two meanders, the USACE HEC-GeoRAS tool for ArcGIS (version 9.2, Environmental Systems Research Institute [ESRI], San Diego, California, written commun., 2008) was used to process survey data for import into HEC-RAS. The relative straightness of the Bull Creek study reach allowed use of the USGS Slope Area Measurement (SAM 2.1) program (Hortness, 2004) to prepare the survey data. Friction properties for each cross-section of the study reaches were represented by Manning's roughness coefficients that were determined by using engineering judgment derived from empirical relations and photographs, as described below.

Data Acquisition and Processing Methods

The Fremont River and Bull Creek study reaches were surveyed using a real-time kinematic global positioning system (RTK-GPS). RTK-GPS allows for accurate and rapid acquisition of real-world coordinate and elevation data. Target cross-sections that generally defined the shape and path of flood streamflows for the study reaches were identified prior to the survey. These cross-sections, along with hydraulic structures, such as bridges and culverts, and land features, such as likely flood plain boundaries, were surveyed using the RTK-GPS. Data were collected at over 1,500 points in the two study reaches during December 3–5, 2007 (fig. 5). Some cross-sections in the Bull Creek study reach were supplemented with elevation data obtained from the 10 m National Elevation Dataset (NED) Digital Elevation Model (DEM) (U.S. Geological Survey, 1999). Vertical accuracies of the NED DEM are reported to be plus or minus 15 m. Adjustments to elevations obtained from the DEM were necessary and were determined on the basis of computed differences between the nearest surveyed point and the DEM. A 5-m DEM from existing orthophotographs and digital terrain models (Utah Automated Geographic Reference Center, 2007) also was examined, but it was not used to supplement the surveyed cross-sections of the Bull Creek reach because it contained greater variability in the elevation data than the 10-m DEM.

Horizontal and vertical coordinate data surveyed with the RTK-GPS were collected relative to a portable base station setup over three temporary stable reference points with unknown survey control in the Hanksville, Utah, area. For each reference point, continuous location data were logged by the base station for more than 4 hours. Following data collection, the logged base station data were processed by the National Geodetic Survey (NGS) Online Positioning User Service (OPUS) to obtain a precise location and elevation solution for each base-station setup using the NGS National Spatial Reference System (NSRS). Horizontal accuracies for the three base-station locations ranged from 0.010 to 0.059 ft and vertical accuracies ranged from 0.007 to 0.046 ft. After the precise solutions were determined for the three base-station setups, the adjustments were applied to the survey points. All elevations are orthometric heights converted from ellipsoid heights using the geoid model GEIOD03 (National Geodetic Survey, 2004).

Fremont River

The HEC-GeoRas tool for ArcGIS uses a continuous DEM to define and export the geometric channel properties used in HEC-RAS models. A DEM for the Fremont River study reach was created by first manually interpolating the acquired survey data that were then geostatistically interpolated to obtain a continuous topographic surface. Interpolation tools contained in the USGS Multi-Dimensional Surface Water Modeling System (MD_SWMS) were used in conjunction with a high-resolution aerial photograph from 2006 to manually create an unordered DEM of the Fremont River study reach. The manual interpolation was done because the survey data were too sparse for geostatistical interpolation algorithms, and the manual interpolation ensured an accurate representation of the unsurveyed portions in the study reach. The unordered DEM was imported into ArcGIS and a geostatistical interpolation technique, ordinary kriging, was used to create a continuous and representative land surface. The HEC-GeoRAS tool was used to define the channel centerline, the overbank margins, and 40 cross-sections (fig. 6). These parameters and cross-sections were then exported from ArcGIS using the HEC-GeoRAS tool and imported into HEC-RAS. Using the HEC-RAS bridge and culvert tool, the Utah State Road 24 Bridge, the only bridge in the study reach, was modeled from measurements made during the reach survey. Appendix A contains the HEC-RAS geometry file for the Fremont River model.

The water-surface elevation at the downstream boundary was set at normal depth (Federal Emergency Management Agency, 2003) in HEC-RAS using the downstream channel slope of 0.0021 ft/ft. The 1-percent chance peak streamflow of 21,400 ft^3/s was set at the upstream boundary. From this steady-state simulation, water-surface elevations for each of the 40 cross-sections were obtained by using the energy equation method.

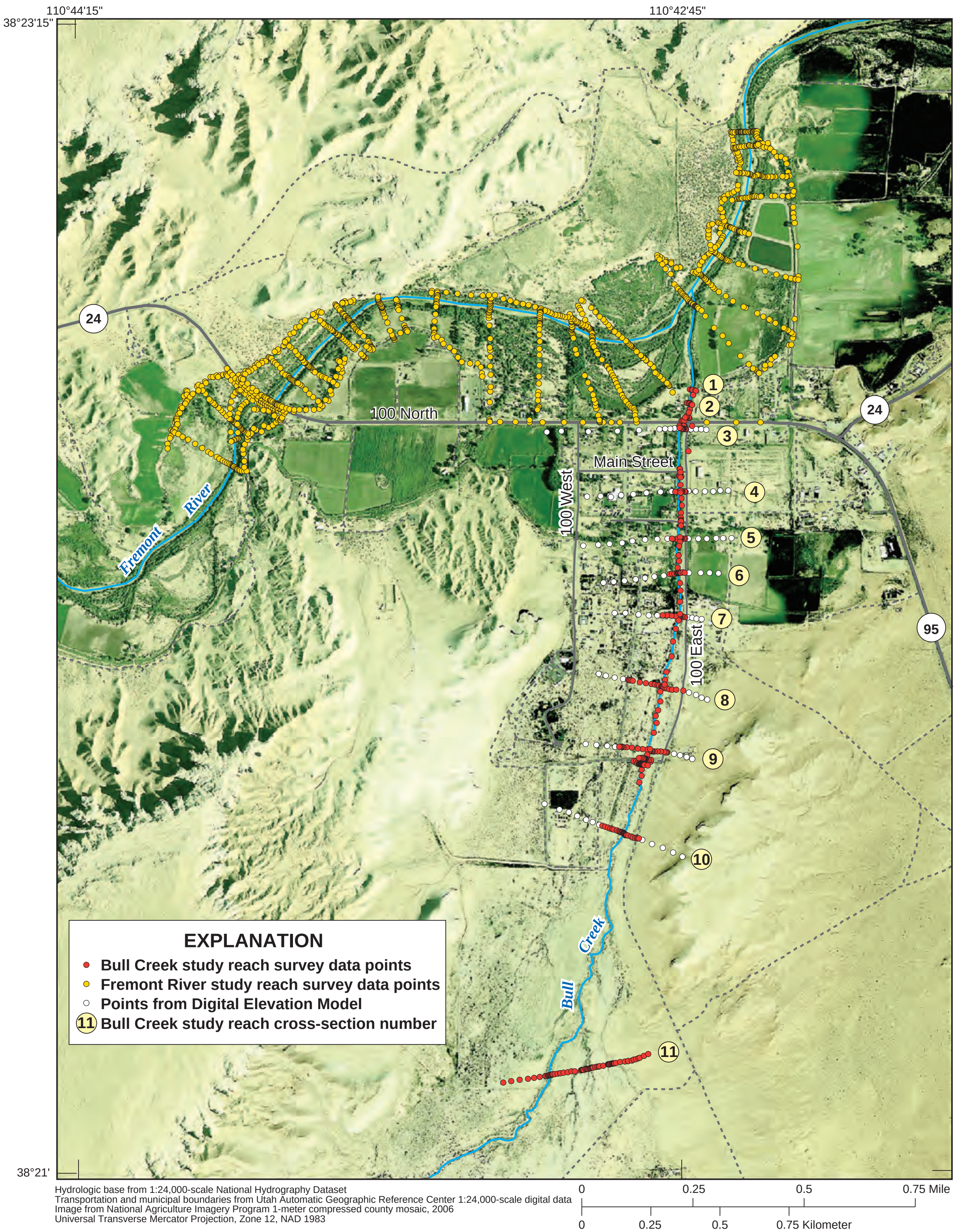

Figure 5. Individual survey data points for the Fremont River and Bull Creek study reaches, Utah.

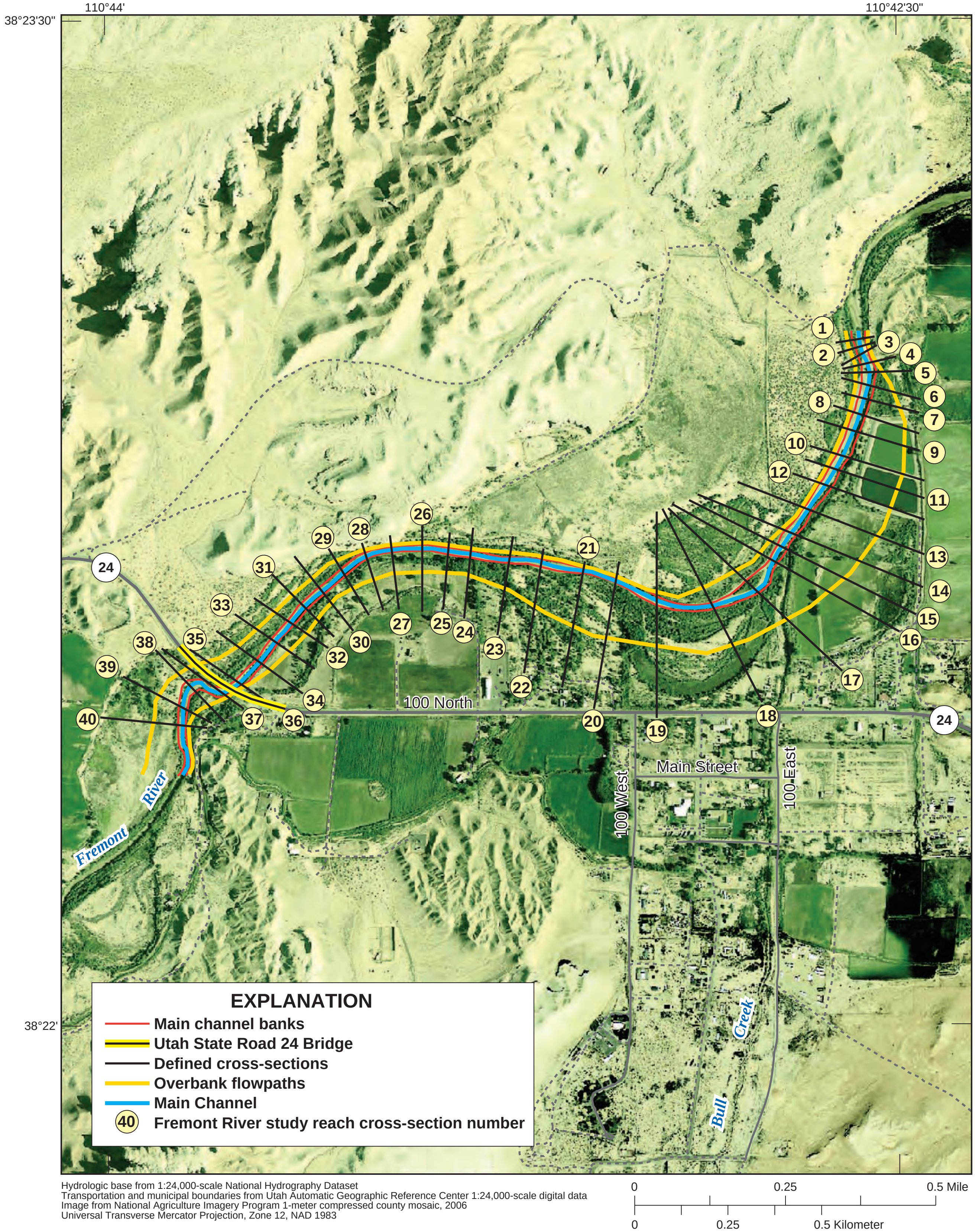

Figure 6. Reach characteristics and cross-sections that were input into HEC-RAS for the Fremont River study reach, Utah.

Bull Creek

The USGS SAM 2.1 computer program was used to straighten surveyed cross-sections and transform the coordinate data from the Bull Creek study reach into the cross-section format of channel station and elevation for import into HEC-RAS. SAM 2.1 is limited for use in channels that are relatively straight, and the Bull Creek study reach met this criteria. River stations as well as cross-section shape, defined by pairings of cross-section station and elevation, were computed by SAM 2.1 and written in HEC-2 file format. In HEC-RAS, the overbank stations were defined from the general shape of the surveyed cross-sections along with photographs taken during the survey. Three hydraulic structures, two culverts, and one small bridge (fig. 1), were modeled in HEC-RAS using the bridge and culvert tool from measurements made during the reach survey. Appendix B contains the HEC-RAS geometry file for the Bull Creek model.

The water-surface elevation at the downstream boundary was set at normal depth (Federal Emergency Management Agency, 2003) in HEC-RAS using the downstream channel slope of 0.0087 ft/ft. The 1-percent chance peak streamflow of 3,960 ft^3/s was set at the upstream boundary. From this steady-state simulation, water-surface elevations for each of the 11 cross-sections were obtained by using the energy equation method. Pressure and weir-flow solutions at the hydraulic structures in the study reach were found to produce the same water-surface elevations as the energy-based method.

Determination of Roughness Characteristics

The conveyance of water in open channels is controlled by the physical characteristics of the channel including geometry, slope, and friction or roughness. Channel roughness is a measurement of the frictional characteristics of the bounding channel materials that cause energy losses in streamflow. Whereas geometry and slope are properties that are relatively easy to measure, roughness often changes with streamflow depth. Because channel roughness varies with depth, the calibration of one-dimensional hydraulic models is an iterative process of adjusting channel roughness values for an observed streamflow until measured water-surface elevations match those predicted by the model. In HEC-RAS, three roughness values are required for each individual cross-section: the main channel, left overbank, and right overbank. For the Fremont River and Bull Creek study reaches, no water-surface elevation data for an observed streamflow were available, and therefore, the developed models are considered uncalibrated. Estimates of channel roughness characteristics, represented by Manning's n values, for cross-sections in the study reaches were determined from existing tables for specific materials (Chow, 1959) and comparison of study reach photographs with photographs of streams with determined roughness values (Barnes, 1967; Phillips and Ingersoll, 1998; Hicks and Mason, 1998). When selecting roughness values, considerations were made for the effect of large streamflows on vegetation where appropriate (Phillips and others, 1998).

For the Fremont River study reach, selected Manning's n values for the main channel portions of the 40 cross-sections were all 0.035 (table 3). The main channel of the Fremont River study reach is almost exclusively composed of silt and sand. Manning's n values for the left overbank areas of the cross-sections ranged from 0.037 to 0.050, and the right overbank areas ranged from 0.037 to 0.085 (fig. 2). The higher Manning's n values were assigned to areas with dense vegetation, specifically on the right overbank of cross-sections 38 through 40. Selected Manning's n values for the Bull Creek study reach ranged from 0.030 to 0.040 (table 4).

Results

Flooding, or inundation, associated with the 1-percent chance peak streamflows for the Fremont River and Bull Creek study reaches was mapped on an aerial photograph taken in 2006 (figs. 7 and 8 and supplemental map). These maps represent likely locations of floodwater associated with simulated streamflows of 21,400 ft^3/s and 3,960 ft^3/s for the Fremont River and Bull Creek study reaches, respectively.

Fremont River

From the steady-flow HEC-RAS analysis, water-surface elevations along with other hydraulic parameters for each of the defined cross-sections were determined (table 5). Water-surface elevations were exported from HEC-RAS and imported into ArcGIS. The HEC-GeoRAS tool for ArcGIS was used to create an interpolated grid of the water-surface slope for the Fremont River study reach. To determine the predicted areas of inundation, HEC-GeoRAS was used to subtract the water-surface elevation grid from the geostatistically interpolated DEM of the Fremont River study reach.

As shown in figure 7, the 1-percent chance peak streamflow determined for the Fremont River study reach generally is contained within an observed flood plain bounded by banks that, in many places exceed 10 ft in height (fig. 2). The inundation map for the Fremont River study reach does not indicate any direct flooding of residences within the town of Hanksville, Utah; however, some agricultural lands and related structures adjacent to the river appear to be flooded. The elevations of the levees of the wastewater treatment ponds located north of town are higher than the estimated water-surface elevations associated with the 1-percent chance peak streamflow. The water-surface elevation at the Utah State Road 24 Bridge is predicted to be about 4,294.7 ft—about 10 ft below the low chord of the bridge deck. The predicted water-surface elevation profile for the Fremont River study reach is shown in figure 9.

Table 3. Manning's roughness coefficients and predicted water-surface elevations for Fremont River study reach, Utah.

Cross-section number (down-stream to upstream)	Manning's roughness coefficients, dimensionless				Predicted water-surface elevation, in feet		
	Left overbank	Main channel	Right overbank	Computed total for cross-section	Using selected Manning's roughness coefficients	20-percent increase in selected Manning's roughness coefficients	20-percent decrease in selected Manning's roughness coefficients
1	0.045	0.035	0.040	0.037	4,279.16	4,280.45	4,277.74
2	0.045	0.035	0.037	0.037	4,279.48	4,280.71	4,278.13
3	0.045	0.035	0.037	0.037	4,279.74	4,280.93	4,278.52
4	0.045	0.035	0.040	0.038	4,280.69	4,281.70	4,279.76
5	0.045	0.035	0.045	0.040	4,280.96	4,281.93	4,280.06
6	0.045	0.035	0.050	0.042	4,281.02	4,282.00	4,280.10
7	0.045	0.035	0.050	0.042	4,281.12	4,282.10	4,280.21
8	0.045	0.035	0.045	0.038	4,280.82	4,281.89	4,279.79
9	0.048	0.035	0.042	0.039	4,281.19	4,282.26	4,280.15
10	0.045	0.035	0.045	0.038	4,281.22	4,282.36	4,280.06
11	0.045	0.035	0.045	0.038	4,281.47	4,282.64	4,280.23
12	0.042	0.035	0.045	0.038	4,281.89	4,283.00	4,280.76
13	0.045	0.035	0.050	0.046	4,282.89	4,283.82	4,282.03
14	0.045	0.035	0.055	0.048	4,282.99	4,283.91	4,282.12
15	0.045	0.035	0.050	0.045	4,283.04	4,283.96	4,282.17
16	0.045	0.035	0.050	0.046	4,283.07	4,284.00	4,282.20
17	0.045	0.035	0.050	0.044	4,283.18	4,284.10	4,282.31
18	0.050	0.035	0.065	0.053	4,283.27	4,284.21	4,282.36
19	0.045	0.035	0.070	0.056	4,283.66	4,284.61	4,282.71
20	0.040	0.035	0.060	0.047	4,283.05	4,284.72	4,283.29
21	0.042	0.035	0.065	0.050	4,285.40	4,285.79	4,284.25
22	0.045	0.035	0.065	0.042	4,286.47	4,286.52	4,286.47
23	0.045	0.035	0.050	0.043	4,289.12	4,289.45	4,288.78
24	0.045	0.035	0.045	0.040	4,289.53	4,290.05	4,288.95
25	0.045	0.035	0.045	0.039	4,289.58	4,290.28	4,288.71
26	0.045	0.035	0.045	0.039	4,290.23	4,290.99	4,289.22
27	0.045	0.035	0.045	0.039	4,291.22	4,291.92	4,290.53
28	0.037	0.035	0.042	0.038	4,292.15	4,292.75	4,291.60
29	0.037	0.035	0.040	0.037	4,292.61	4,293.19	4,292.08
30	0.040	0.035	0.045	0.040	4,292.83	4,293.44	4,292.26
31	0.045	0.035	0.050	0.041	4,292.83	4,293.52	4,292.16
32	0.045	0.035	0.040	0.040	4,293.37	4,293.99	4,292.78
33	0.045	0.035	0.042	0.041	4,293.51	4,294.16	4,292.89
34	0.045	0.035	0.040	0.039	4,293.55	4,294.27	4,292.79
35	0.045	0.035	0.040	0.039	4,293.49	4,294.35	4,292.48
36	0.045	0.035	0.040	0.041	4,294.72	4,295.28	4,294.29
37	0.040	0.035	0.060	0.041	4,295.14	4,295.70	4,294.71
38	0.040	0.035	0.080	0.047	4,295.14	4,295.74	4,294.65
39	0.050	0.035	0.085	0.048	4,295.18	4,295.85	4,294.59
40	0.045	0.035	0.080	0.042	4,295.37	4,296.12	4,294.59

Table 4. Manning's roughness coefficients and predicted water-surface elevations for Bull Creek study reach, Utah.

Cross-section number (down-stream to upstream)	Manning's roughness coefficients, dimensionless				Predicted water-surface elevation, in feet		
	Left overbank	Main channel	Right overbank	Computed total for cross-section	Using selected Manning's rough-ness coefficients	20-percent increase in selected Manning's roughness coefficients	20-percent decrease in selected Manning's roughness coefficients
1	0.040	0.035	0.040	0.035	4,284.61	4,285.69	4,283.66
2	0.040	0.035	0.040	0.035	4,285.93	4,287.06	4,285.14
[1]2A	0.040	0.035	0.036	0.035	4,291.44	4,291.44	4,291.44
[1]2B	0.040	0.035	0.036	0.039	4,300.65	4,300.65	4,300.65
3	0.040	0.035	0.040	0.039	4,300.65	4,300.65	4,300.65
[1]3A	0.040	0.035	0.038	0.035	4,300.29	4,300.30	4,300.29
[1]3B	0.040	0.035	0.038	0.038	4,303.17	4,303.13	4,303.14
4	0.040	0.035	0.040	0.038	4,303.19	4,303.16	4,303.14
[1]4A	0.040	0.035	0.040	0.035	4,302.60	4,302.69	4,302.46
[1]4B	0.040	0.035	0.040	0.038	4,306.93	4,307.45	4,306.44
5	0.040	0.035	0.040	0.038	4,306.96	4,307.47	4,306.45
6	0.040	0.035	0.040	0.035	4,305.07	4,306.33	4,305.07
7	0.040	0.030	0.040	0.033	4,310.34	4,310.54	4,310.10
8	0.040	0.030	0.040	0.035	4,317.45	4,317.45	4,317.45
9	0.040	0.030	0.040	0.034	4,323.17	4,323.17	4,323.17
10	0.040	0.035	0.040	0.039	4,330.18	4,330.45	4,330.18
11	0.040	0.040	0.040	0.040	4,351.29	4,351.50	4,350.71

[1] Interpolated cross section

To provide some constraints on the uncertainty associated with the uncalibrated nature of the model, the selected Manning's n values were first increased and then decreased by 20 percent, and predicted water-surface elevations were compared with those related to the selected Manning's n values (table 3). The largest increase in water-surface elevation was 1.67 ft at cross-section 20, and the largest decrease was 1.42 ft at cross-section 1. The average change in water-surface elevation for the 20-percent increase in Manning's n values was 0.83 ft, and the average change for the 20-percent decrease was -0.80 ft.

Bull Creek

From the steady-flow HEC-RAS analysis, water-surface elevations along with other hydraulic parameters for each of the 11 cross-sections were determined (table 6). The water-surface elevations were then manually matched to the survey and DEM data for the Bull Creek study reach, and the predicted inundation was mapped. Inundation between the cross-sections was manually interpolated.

As shown in figure 8, the 1-percent chance peak streamflow of 3,960 ft^3/s for the Bull Creek study reach is predicted to inundate a substantial portion of Hanksville, Utah, west of Bull Creek. The predicted water-surface elevation profile for the Bull Creek study reach is shown in figure 10. The main cause for this flooding appears to be water backing up behind one small bridge and two culverts at 100 South, Main Street, and Utah State Road 24 (100 North). The predicted water-surface elevations at the bridge and culverts are higher than the road-deck elevations. These results indicate that the bridge and culverts are undersized. Photographs of the bridge and one of the culverts are shown in figures 11 and 12. To examine the possibility that the bridge and culverts are undersized and causing the large inundation, a second simulation was done in which the bridge and culverts were removed from the HEC-RAS model. In this simulation, the overbank flooding was limited to the upstream portions of the reach, and the flow was fully contained within the main channel at the locations where the culverts were removed.

Similar to the Fremont River model, the uncertainty associated with the uncalibrated nature of the Bull Creek model was examined by increasing and decreasing the selected Manning's n values by 20 percent (table 4). The largest increase in water-surface elevation was 1.26 ft, at cross-section 4A, and the largest decrease was 0.95 ft, at cross-section 1. The average change in water-surface elevation for the 20-percent increase in Manning's n values was 0.31 ft, and the average change for the 20-percent decrease was -0.22 ft.

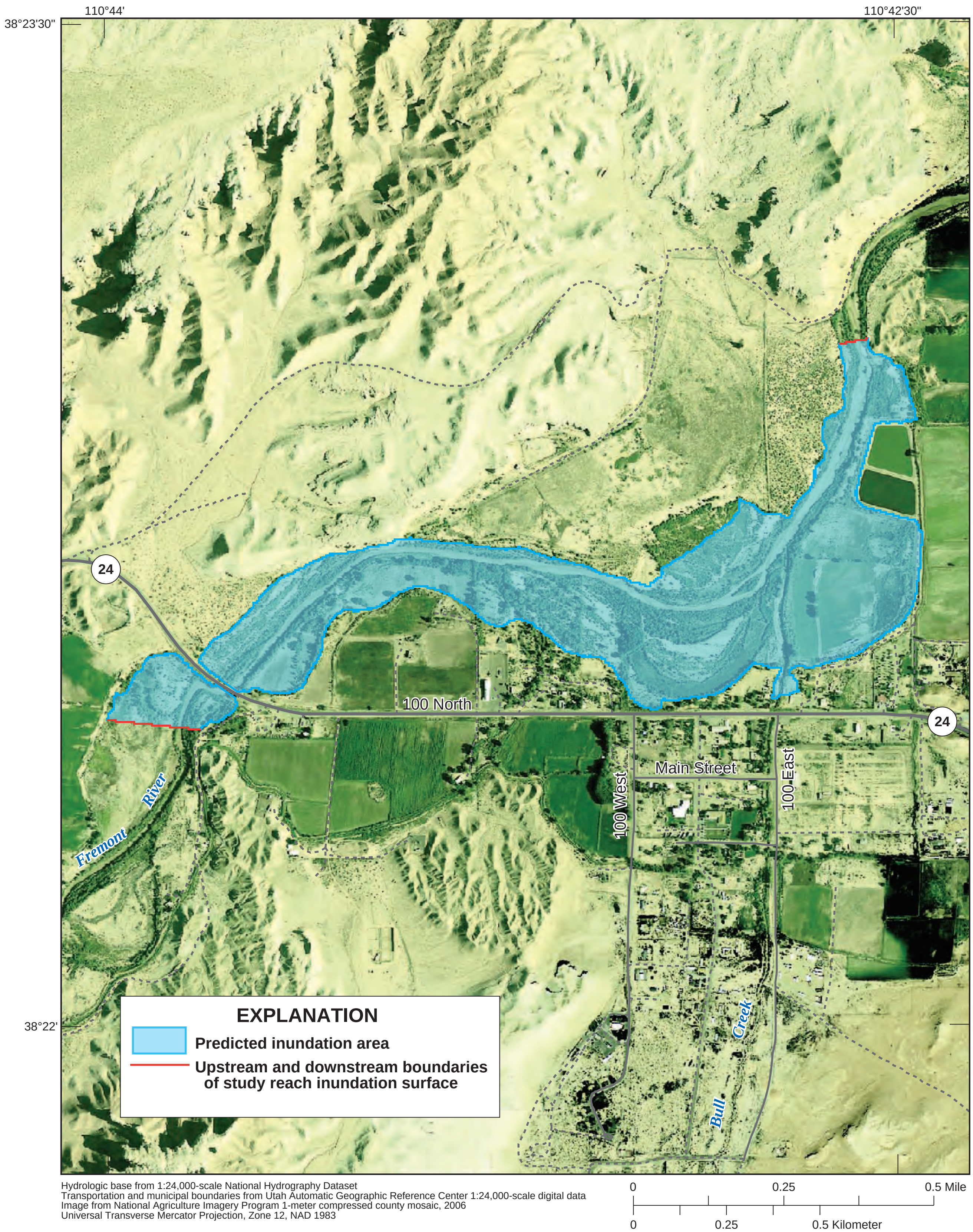

Figure 7. Predicted inundation associated with the 1 percent chance peak streamflow for the Fremont River study reach, Utah.

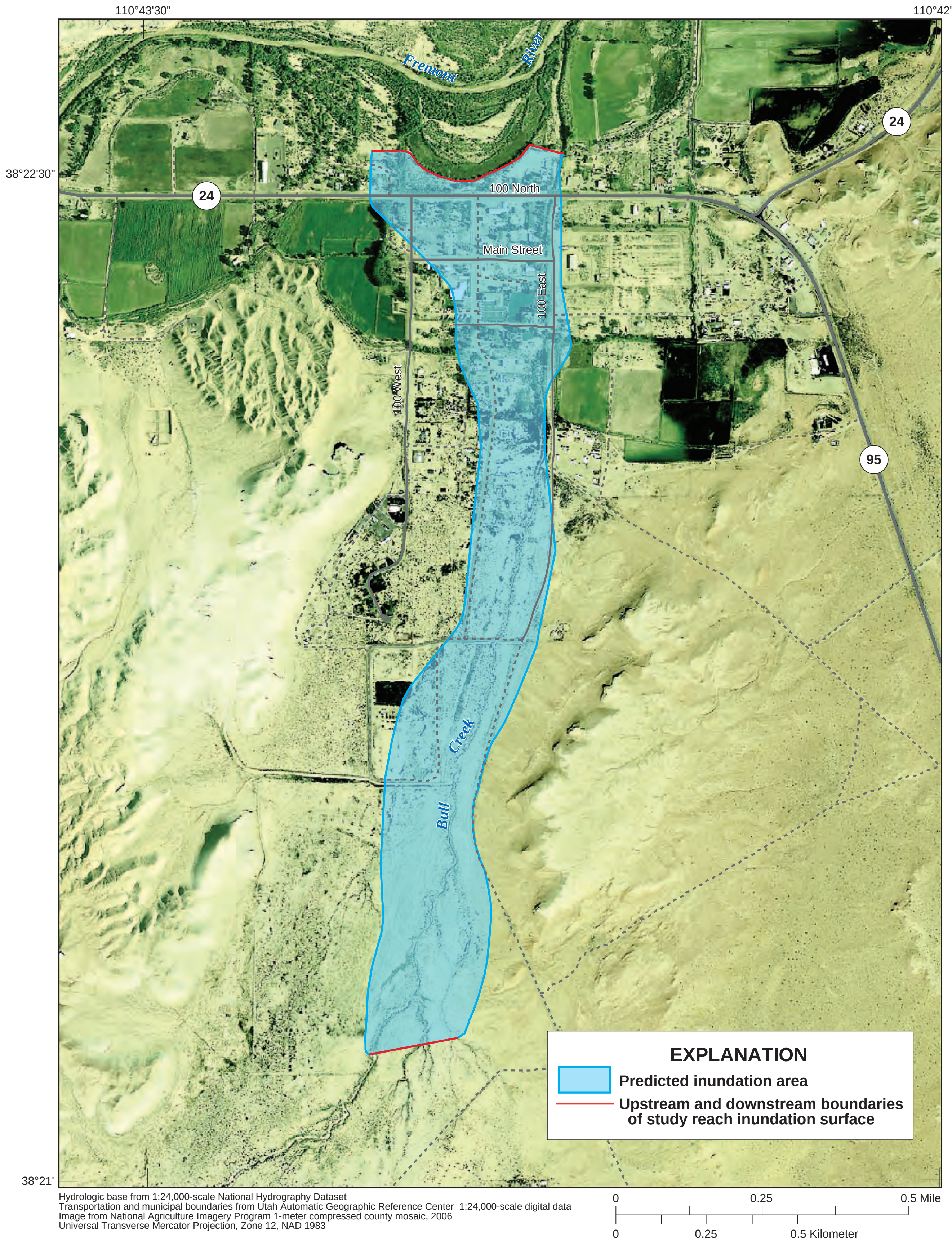

Figure 8. Predicted inundation associated with the 1 percent chance peak streamflow for the Bull Creek study reach, Utah.

Table 5. Predicted hydraulic parameters for cross-sections of the Fremont River study reach, Utah.

Cross-section number (downstream to upstream)	Cumulative channel length from downstream model boundary, in feet	Minimum channel elevation, in feet	Predicted water-surface elevation, in feet	Mean channel velocity, in feet per second	Flow area, in square feet	Top width of flow area, in feet	Froude number, dimensionless
1	0	4,263.65	4,279.16	11.01	2,438.35	270.55	0.53
2	68.6	4,264.17	4,279.48	10.78	2,533.54	267.41	.52
3	131.7	4,264.09	4,279.74	10.36	2,636.52	272.73	.50
4	232.5	4,264.14	4,280.69	7.10	4,195.97	424.86	.32
5	317.5	4,264.17	4,280.96	5.68	5,476.73	547.26	.25
6	436.1	4,264.29	4,281.02	5.97	5,683.97	609.99	.26
7	561.9	4,264.66	4,281.12	5.75	6,106.84	676.89	.25
8	709.7	4,264.98	4,280.82	8.72	3,340.58	353.92	.40
9	868.6	4,265.35	4,281.19	8.00	3,839.55	434.19	.37
10	1,116.6	4,265.94	4,281.22	9.52	3,009.33	328.98	.44
11	1,253.3	4,265.83	4,281.47	9.64	3,175.27	402.85	.45
12	1,424.4	4,266.48	4,281.89	8.89	3,404.76	398.31	.41
13	1,694.3	4,266.83	4,282.89	4.32	9,619.01	1,228.16	.20
14	1,959.2	4,267.10	4,282.99	3.87	12,040.44	1,772.23	.18
15	2,110.8	4,267.55	4,283.04	3.80	11,863.38	1,822.34	.18
16	2,257.8	4,268.27	4,283.07	4.30	10,810.33	1,814.82	.21
17	2,580.8	4,268.25	4,283.18	3.58	10,796.71	1,572.73	.18
18	2,999.3	4,269.29	4,283.27	6.15	8,091.51	1,193.97	.30
19	3,512.2	4,270.36	4,283.66	6.51	7,806.49	1,163.19	.32
20	3,926.0	4,271.45	4,283.05	16.52	3,031.16	739.49	.87
21	4,235.6	4,271.90	4,285.40	12.88	4,071.66	796.67	.63
22	4,623.2	4,272.59	4,286.47	15.58	2,707.42	616.20	.76
23	4,916.2	4,273.33	4,289.12	10.26	4,163.88	705.26	.46
24	5,272.1	4,274.06	4,289.53	11.16	3,419.18	536.55	.50
25	5,476.3	4,274.43	4,289.58	12.98	2,796.55	451.29	.60
26	5,713.0	4,275.47	4,290.23	12.53	2,741.04	420.30	.59
27	5,989.3	4,275.66	4,291.22	10.93	3,147.58	468.47	.50
28	6,230.2	4,275.98	4,292.15	8.26	4,015.71	532.11	.37
29	6,486.2	4,276.43	4,292.61	7.03	4,662.41	585.45	.31
30	6,741.1	4,277.01	4,292.83	6.90	4,785.22	529.66	.31
31	6,938.6	4,277.36	4,292.83	8.61	4,389.89	605.24	.39
32	7,145.4	4,277.54	4,293.37	6.36	5,707.96	723.78	.29
33	7,369.3	4,278.33	4,293.51	6.47	5,758.40	785.33	.30
34	7,602.9	4,279.17	4,293.55	7.94	4,679.49	834.10	.39
35	7,865.2	4,280.12	4,293.49	11.08	3,063.72	523.06	.56
36	7,932.2	4,280.43	4,294.72	5.20	6,534.21	795.75	.25
37	8,044.2	4,280.43	4,295.14	4.92	6,874.77	800.31	.23
38	8,374.8	4,281.09	4,295.14	6.42	6,139.65	824.66	.31
39	8,586.0	4,281.79	4,295.18	8.52	5,034.99	784.67	.42
40	8,746.7	4,282.32	4,295.37	9.10	4,314.55	840.05	.47

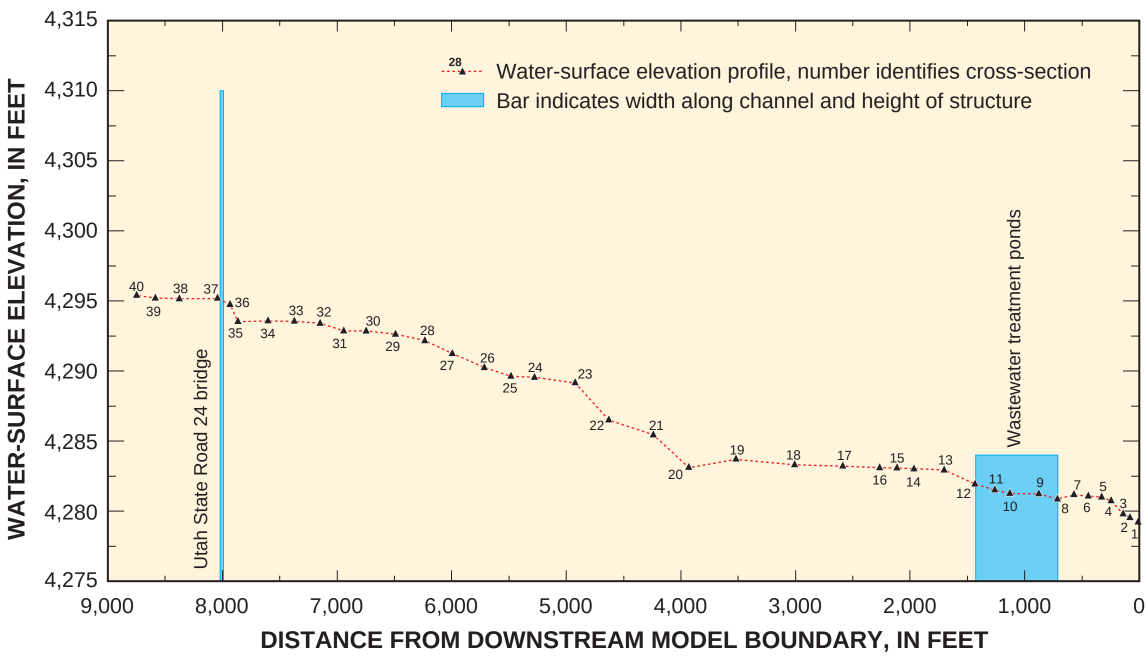

Figure 9. Predicted water-surface elevation profile for the 1-percent chance peak streamflow for the Fremont River study reach, Utah.

Table 6. Predicted hydraulic parameters for cross-sections of Bull Creek study reach, Utah.

Cross-section number (down-stream to upstream)	Cumulative channel length from downstream model boundary, in feet	Minimum channel elevation, in feet	Predicted water-surface elevation, in feet	Mean channel velocity, in feet per second	Flow area, in square feet	Top width of flow area, in feet	Froude number, dimensionless
1	0	4,273.80	4,284.61	13.44	294.60	37.31	0.84
2	164	4,275.20	4,285.93	14.06	281.58	34.93	.87
12A	356	4,282.15	4,291.44	14.64	270.58	40.70	1.00
12B	430	4,283.01	4,300.65	0.84	8,301.96	1,718.61	.04
3	465	4,282.70	4,300.65	0.82	8,245.19	1,718.68	.04
13A	648	4,282.56	4,300.29	6.04	892.70	489.08	.33
13B	738	4,284.51	4,303.17	2.58	3,111.25	972.95	.13
4	918	4,285.70	4,303.19	3.06	2,724.87	975.28	.15
14A	1,300	4,289.29	4,302.60	8.86	460.06	72.90	.51
14B	1,325	4,289.29	4,306.93	2.57	3,177.04	1,007.28	.12
5	1,485	4,290.40	4,306.96	2.86	2,874.43	1,010.57	.15
6	1,911	4,293.40	4,305.07	14.62	270.94	40.86	1.00
7	2,405	4,299.70	4,310.34	8.97	755.28	379.99	.61
8	3,207	4,307.00	4,317.45	8.72	1,049.18	781.41	.60
9	4,008	4,311.80	4,323.17	8.88	951.40	683.98	.60
10	4,962	4,322.50	4,330.18	9.79	587.84	376.90	.98
11	8,114	4,344.70	4,351.29	3.42	1,166.91	658.15	.43

[1] Interpolated cross section

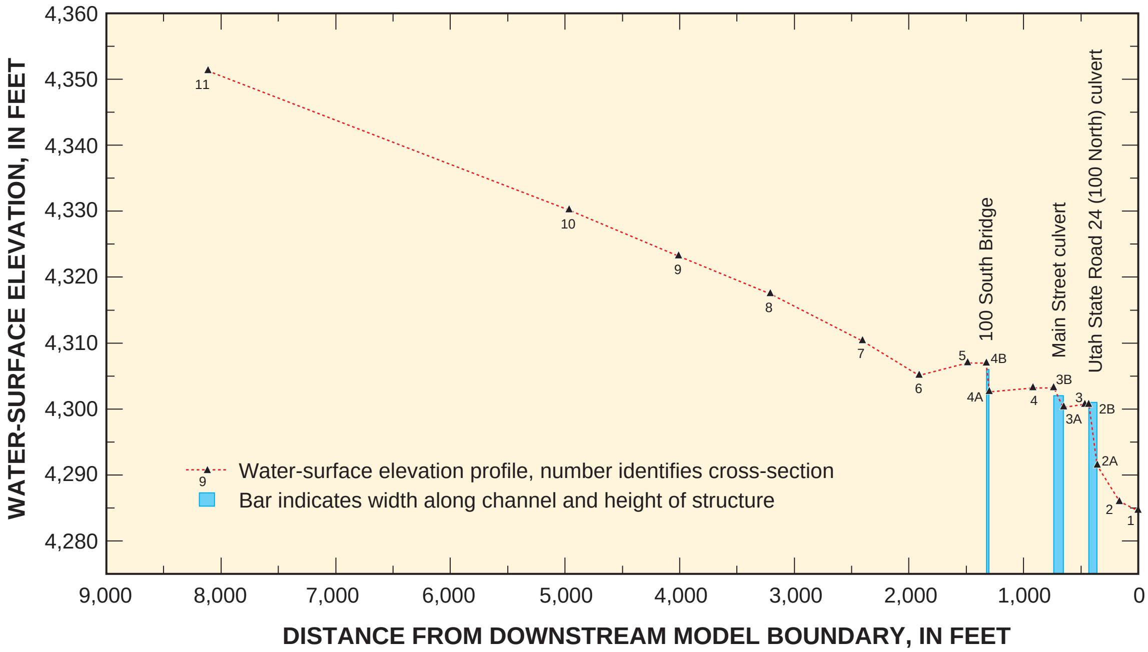

Figure 10. Predicted water-surface elevation profile for the 1-percent chance peak streamflow for the Bull Creek study reach, Utah.

Figure 11. 100 South Bridge in Bull Creek, Utah.

Figure 12. Main Street culvert in Bull Creek, Utah.

Model Limitations

Certain limitations should be considered when interpreting the results presented in this report. The one-dimensional hydraulic models developed for the Fremont River and Bull Creek study reaches were not calibrated from any observed streamflows or water-surface elevations. Actual roughness characteristics of the main channel and overbank regions may be higher, which would cause water-surface elevations to be higher than predicted, or lower, which would have the opposite effect. The processes associated with channel scour and fill were not considered in this analysis, that is to say, the geometric shapes of the cross-sections modeled were assumed to remain fixed under the flow conditions examined. Similarly, channel migration caused by bank erosion associated with the simulated streamflows was not considered.

The one-dimensional methods used required a simplification of the study reach topography into a series of distinct cross-sections that were generally perpendicular to the direction of streamflow. To obtain these cross-sections for the Fremont River study reach, discrete survey points underwent a series of interpolations to develop a continuous grid surface from which cross-section geometries were defined. These defined cross-sections are assumed to represent the general shape of the flood flow channel. The overbank regions of many of the Bull Creek study reach cross-sections were supplemented with adjusted DEM data. DEM data used before adjustment was on average 7 ft lower than the nearest surveyed point.

The uncertainties associated with estimates of the 1-percent chance peak streamflows should also be considered when interpreting the results presented in this report. The 1-percent chance peak streamflow estimate of 3,960 ft^3/s for Bull Creek in the town of Hanksville, Utah, as determined in this study, contains a large amount of uncertainty. To obtain this streamflow estimate required the application of a variety of statistical methods. Flood frequency estimates, such as the 1-percent chance peak streamflow, for specific locations can be improved with long-term streamflow data. These data can be acquired most economically with crest-stage gaging stations.

The methods used to determine the 1-percent chance peak streamflows assumed that the annual time series of peak streamflows for the Fremont River and Bull Creek study reaches were unaffected by regulation or urbanization and were the result of natural atmospheric and physiographic conditions. The results presented in this report are specific to the same conditions. Modifications to the drainage basin upstream of Hanksville, Utah, including urban development, water diversions, or even wildfire, may increase or decrease the 1-percent chance peak streamflow and associated inundation.

The simulated flood flows associated with the study reaches were assumed independent of one another, and streamflow in one reach was not considered when modeling streamflow in the other reach. Simultaneous high flows in the two reaches may cause backwater conditions that could increase water-surface elevations and inundated area. It also was assumed that no debris existed in the streams, which could cause backwater conditions to manifest.

Summary

Flooding associated with the 1-percent chance (100-year) peak streamflows for the Fremont River and Bull Creek in Hanksville, Utah, was delineated by using one-dimensional hydraulic models. The 1-percent chance peak streamflow for the Fremont River was determined to be 21,400 ft^3/s using annual peak streamflow-gaging station records from USGS crest-stage gaging station 09330400, Fremont River near Hanksville, Utah, which were adjusted using records from USGS streamflow-gaging station 09333500 Dirty Devil River above Poison Spring Wash near Hanksville, Utah. The 1-percent chance peak streamflow for Bull Creek was determined to be 3,960 ft^3/s using a combination of annual peak streamflow data from upstream USGS streamflow-gaging station 09330410, Bull Creek near Hanksville, Utah, which were adjusted using records from USGS streamflow-gaging station 09329050, Seven Mile Creek near Fish Lake, Utah, and regional peak flow regression equations. These determined streamflows were simulated in reach-specific, one-dimensional hydraulic models. Survey data along with supplemental DEM data for Bull Creek were processed into cross-sections for each study reach using various software modeling programs. The 1-percent chance flood plain for the Fremont River in Hanksville, Utah, generally flooded agricultural lands and did not encroach upon the town. The 1-percent chance flood plain on the west side of Bull Creek was found to include a large portion of the town of Hanksville, Utah. Specific limitations associated with uncertainties in the determined 1-percent chance peak streamflows, required simplifications of one-dimensional modeling, and a lack of model calibration should be considered when interpreting the results presented in this report.

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Appendix A.

HEC-RAS geometry file for Fremont River model

Appendix B.

HEC-RAS geometry file for Bull Creek model

Supplemental Map

The supplemental map shown here is for the convenience of the reader, and has been reduced in size. A larger map is available, and can be downloaded at: http://pubs.usgs.gov/sir/2008/5233

When printing, the reader may wish to print sizes larger than 8.5 x 11 inches. Use the “Scale to fit paper” and select a larger paper size or, if larger paper sizes are not an option, use the ‘Tile’ option. The ‘Tile’ option allows the reader to print a larger size than the printer would normally allow by printing to multiple pages. See the printer manual for further information.

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By Terry A. Kenney and Susan G. Buto
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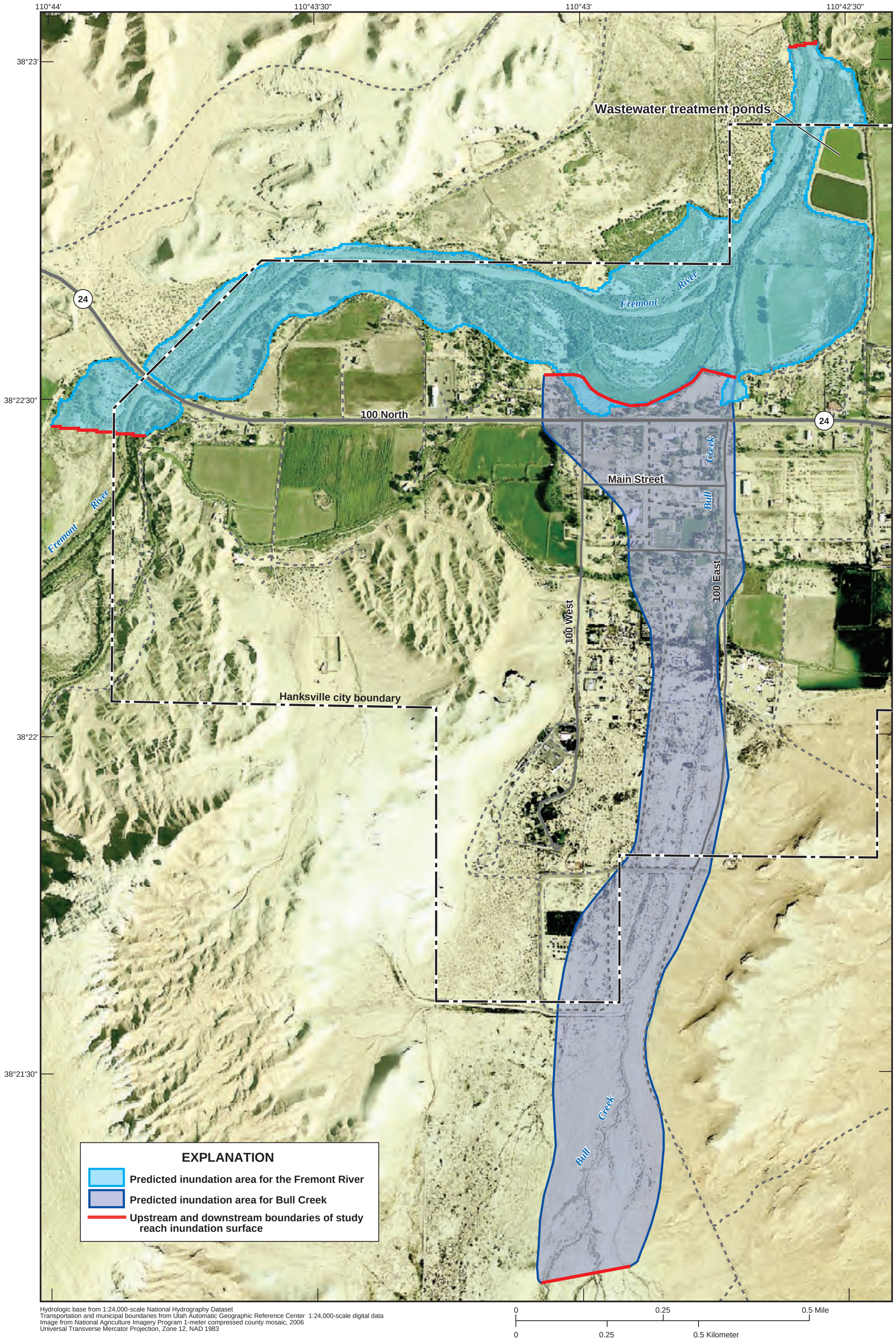

Hydrologic base from 1:24,000-scale National Hydrography Dataset
Transportation and municipal boundaries from Utah Automatic Geographic Reference Center 1:24,000-scale digital data
Image from National Agriculture Imagery Program 1-meter compressed county mosaic, 2006
Universal Transverse Mercator Projection, Zone 12, NAD 1983

Predicted inundation associated with 1 percent chance peak streamflows for the Fremont River and Bull Creek study reaches, Hanksville, Utah

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